Understanding Humans to Better Understand Robots in a Joint-Task Environment:

The Study of Surprise and Trust in Human-Machine Physical Coordination

by

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ABSTRACT

Human-robot interaction has expanded immensely within dynamic environments. The goals of human-robot interaction are to increase productivity, efficiency and safety. In order for the integration of human-robot interaction to be seamless and effective humans must be willing to trust the capabilities of assistive robots. A major priority for human-robot interaction should be to understand how human dyads have been historically effective within a joint-task setting. This will ensure that all goals can be met in human robot settings. The aim of the present study was to examine human dyads and the effects of an unexpected interruption. Humans' interpersonal and individual levels of trust were studied in order to draw appropriate conclusions. Seventeen undergraduate and graduate level dyads were collected from Arizona State University. Participants were broken up into either a surprise condition or a baseline condition. Participants individually took two surveys in order to have an accurate understanding of levels of dispositional and individual levels of trust. The findings showed that participant levels of interpersonal trust were average. Surprisingly, participants who participated in the surprise condition afterwards, showed moderate to high levels of dyad trust. This effect showed that participants became more reliant on their partners when interrupted by a surprising event. Future studies will take this knowledge and apply it to human-robot interaction, in order to mimic the seamless team-interaction shown in historically effective dyads, specifically human team interaction.

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INTRODUCTION

Autonomous relationships are quickly becoming ubiquitous. Humans and robots are hastily becoming two separate entities that must learn to work together. Autonomous agents are rapidly being integrated into several diverse environments, such as; medical fields, industrial fields, educational systems and space exploration. An autonomous agent in this context can be described as a robot designed to encompass human-robot coordination. These are robots developed to engage humans in various collaborative activities, aid in completing a joint task, and extend humans' ability to perform efficiently, extensively, and safely (Sparrow, 2005).

Autonomous agents commonly act unexpectedly, whether this be from an alteration within the environment, a change in human behavior, or a malfunction within the system. In order for a seamless, shared relationship between a human and autonomous agent, researchers must start by understanding human's social qualities, teamwork abilities, and emotions in order to create and design an appropriate agent (Miller, 2017). This will ensure that suitable systems can be designed to communicate and adapt like humans to an ever-changing atmosphere.

Literature shows that up until recently, there has been a gap in trust and human machine interaction. A large emphasis has been placed on trust within human relationships, but as the robotics field has broken ground, human systems researchers have found that accounting for trust within the human robot dyad is often overlooked. Researchers should not only be focused on the mechanics of the system but also how the system interacts with the people and things surrounding it (Jian, 1998).

When designing a system that will extensively aid humans in tedious tasks, researchers must understand that trust is a critical attitude that plays a large role in current and developing relationships. Trust can be exemplified in many different forms; it can be a state of vulnerability, an expectation, or a form of reliance (Lee & See, 2004). Trust is what embodies the success of many relationships. With the robotics field making large head-way in society today, studying multiple dimensions of trust has become essential. Specifically interpersonal and dyad trust, as they have a large effect in developing and continuous relationships (Evans, 2008).

Trust has a large impact within human-robot interaction in several different environments, explicitly the space exploration and industrial setting. Up until now the relationship has been well-established in static environments, with robots performing accurately and efficiently (Gallina, 2015). But as technology increases and the environments become more dynamic, it’s important for researchers to re-examine robots abilities and capabilities in regards to human-robot coordination. Robots are beginning to work in a much more high-stake environment, enlisting a great deal of reliance and trust in their reaction, adaptation, and communication. As robots begin to aid humans in situations involving hazardous chemicals, equipment, and emergency conditions, people must be able to calibrate their levels of trust to the robots capabilities. This will ensure that people have faith in a robots ability to safely increase efficiency and performance (Fong, 2004) (Heyer, 2010).

The focus of this paper is to understand how human dyads develop and adapt to unexpected events within a joint-task environment, and how this effects levels of trust. This research will then be applied to human robot dyads to better understand how to build and design a robot model that can adapt and communicate like a human-being, within these environments. Using humans as a model within these environments is important because humans historically have developed, grown and adjusted to several changing environments. Understanding how humans form levels of trust while acclimating to these unexpected events will give researchers the ability to build robots to be as explainable and adaptable as a human (Miller, 2017).

The research question posed in this study is: Do unexpected events in a joint-task setting affect individual levels of trust when working in a team? Does a disruption created by a team-member, during an unexpected event, have any effect on individual trust levels?

BACKGROUND

Surprise

The emotion of surprise is the result of not following a set recipe. Surprise commonly evokes a feeling of arousal and likely leaves some kind of memorable mark on a human. The feeling of surprise typically happens because an event occurs that is outside of a humans expectations (Loewenstein, 2018). Surprise can create emotions of positivity or negativity depending on the social environment. Nevertheless it usually constructs a need for an explanation or elaboration; humans naturally have a need to make sense of the unexpected situation (Loewenstein, 2018). Surprise differs from startle in that startle is typically a fast, brief, psychological reaction to something. Startle typically looks like a quick eye blink, contraction of facial or body parts, or feelings of fear. Whereas surprise is more of a cognitive, emotional response and likely changes somebody’s understanding of the situation (Landman et al., 2017).

Within many industries, human robot interaction solicits an unexpected feeling of surprise. This unexpected feeling is considered surprise because it causes humans to re-orient their behavior or brings on feelings of curiosity (Landman et al., 2017). Surprise can come in several forms within human robot dyads. This can be within the environment, the mechanics of the robot, or high-stake interaction between the dyad. Robots may be required to aid humans in handling heavy equipment, responding to emergency situations, or completing hazardous tasks. It is common that unexpected events can follow these tasks, such as a loud noise within an industrial factory, natural disasters in an outside setting, or the need for an emergency response in multiple settings (Heyer, 2010) (Fong, 2004). These events have the ability to effect the dyads interaction, requiring that the human and robot can respond and adapt quickly (Gallina, 2015). How the robot acclimates to the unexpected event will greatly affect how the human will trust its abilities (Rempel et al, 1985).

Humans unsurprisingly want an explanation for the unexplainable. Explanations give the ability for humans to have a better understanding of functional capabilities, pragmatic goals, and information processes. If a human feels informed while interacting with a robot, during an unexpected interruption, then it is hypothesized that a human will demonstrate higher levels of trust. An explanation can look like the transfer of knowledge, explaining the causes of the event, or clarifying the desires and goals of the interaction. This will ultimately lead to stronger team connection, leading to a more trusting relationship, this will be discussed in more detail later (Miller, 2017).

Trust

In the context of this study, Lee & See's (2004) definition of trust will be utilized. They define trust as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability." This definition of trust will be used as the base of the entire study because it encompasses both a human dyad and human-robot dyad. When humans are working with autonomous agents they likely are in a new, uncomfortable environment. They may begin to feel vulnerable or at risk. This is often times because a human is unaware of a robots intentions or motives. These feelings are also common amongst human relationships. Feelings of uncertainty and vulnerability must be acknowledged in order help understand how to establish a solid foundation between human-robot dyads in a joint-task setting (Lee & See, 2004).

It's important when looking at trust that a person's individual and cultural backgrounds are considered (Lee & See, 2004). Individual and cultural backgrounds help in understanding a humans baseline levels of trust, prior to any interaction with an outside person or system. Trust is deeply rooted within a human and usually affected by past experiences within the human's lives. These past experiences can influence how a human trusts new, vulnerable situations, such as interacting with an autonomous agent.

Individual context focuses primarily on the individual differences of humans and the events humans have experienced that may affect their levels of trust. This can stem from childhood experiences or any traumatic incident. Cultural context looks at how trust can been influenced by social norms or expectations and is particularly important when looking at human-robot interaction. For decades humans have portrayed robots as being untrusting and dangerous agents. Humans expect that robots do not want to help them.

This can prime the human to enter an autonomous relationship with the idea that the robot will fail them or turn against them. Past experiences may lead them to become untrusting of a robot (Lee & See, 2004).

It is important that when establishing an understanding of how humans trust other entities that their baseline levels of trust are used as a gauge. This gauge will help in empathizing with the human on how and why their interacting the way they are. Designing robots around the human can help in creating a system that responds and adapts to human emotion, attitudes, and behaviors.

An explainable and interpretable robot allows for humans to understand all actions that a robot completes. This in turn can help in priming humans to form a new understanding of robots and their capabilities (Miller, 2017). Before designing an explainable agent, researchers must understand how humans trust and communicate, this will allow researchers to design a robot that can offer human-like qualities (Lee & See, 2004). These human-like qualities can vary from verbal explanations to mechanical adaptations, potentially helping explain why and how the robot is responding to an unexpected event that occurred (Miller, 2017). This allows for the foundation of trust to be established while molding a strong team connection between human and robot (Lee & See, 2004). The relationship between human and robot ultimately relies on human’s ability to trust their intentions. When studying trust, it is important to look at multiple dimensions to fully apprehend how humans trust, this starts with interpersonal trust.

Interpersonal Trust

Interpersonal trust is the perception that the people surrounding you will not doing anything to harm or put you at risk. When an individual has high levels of interpersonal trust, they accept vulnerability. Research has shown that these innate feelings play a large role in how humans trust other people and systems, specifically automation (Atkinson & Clark, 2013). The existence of any social group largely depends on the whether there is trust present. When looking at how humans trust other humans or systems surrounding them, it is important to focus on interpersonal trust.

Julian Rotter (1967) developed an additive, Likert scale in order to help identify individual's levels of trust. The scale incorporates questions focusing on people who hold high stature in a person's life, such as teachers, parents, and powerful government leaders. The goal of the scale was to identify human's levels of interpersonal trust in regards to several different social constructs. High levels of interpersonal trust show that humans trust many different social constructs, whereas low levels of interpersonal trust, show that humans have a hard time trusting. When a human does not demonstrate high levels of trust, they are more likely to monitor or isolate an individual or system. These low-levels of trust can arise from the trust concepts discussed above, individual and cultural differences. Low-levels of trust can also stem from lack of knowledge of a system. Rotter's scale can be used to identify a person's dispositional trust (Rotter, 1967). Dispositional trust gives researchers the ability to measure a baseline level of trust prior to any interaction with human or robot. This baseline level of trust gives researchers an idea of what a humans trust propensity is.

Trust propensity is a human's willingness to trust a system or individual. High levels of interpersonal trust may be linked to higher levels of trust in teammates. The individual differences discussed above have the ability to largely affect how a human trust new and existing partnerships within their lives (Evans, 2008). As researchers begin to understand the development of trust within human-robot dyads, they must first start by understanding how human teams develop, form, and withstand trust (Sheng, 2010). This will allow researchers to create and design a robot that responds and encompasses human attributes (Lee & See 2014 & Miller 2017).

Turkle (2004; 2010) states that today's technology "pushes our Darwinian buttons, exhibiting the kinds of behavior people associate with sentience, intentions, and emotions". This leads to the results that humans unconsciously link social behaviors to technology. If humans view robots as social characters, then it becomes necessary to design a robot that fully encompasses and responds to human attributes (Atkinson & Clark, 2013). Robots must be able to institute a human-like relationship with their partner in order to create a solid foundation between the dyad, this starts with dyad trust (Jian, 1998).

Human-Dyads

Teamwork has the ability to prime higher performance, enhance productivity, and provoke better quality of life. In order to achieve and reach the goals a team has to offer, trust is critical within the relationship. When a human feels their partner has the ability to offer team support, they begin to institute team-like behaviors, such as, working together, communicating, and accomplishing each other's goals. The team members begin to calibrate an appropriate level of trust, meaning they trust their partner based on the attributes they've shown them (Lee & See, 2004). This ultimately leads to commitment within the team. See Figure 1A below (Sheng, 2010).

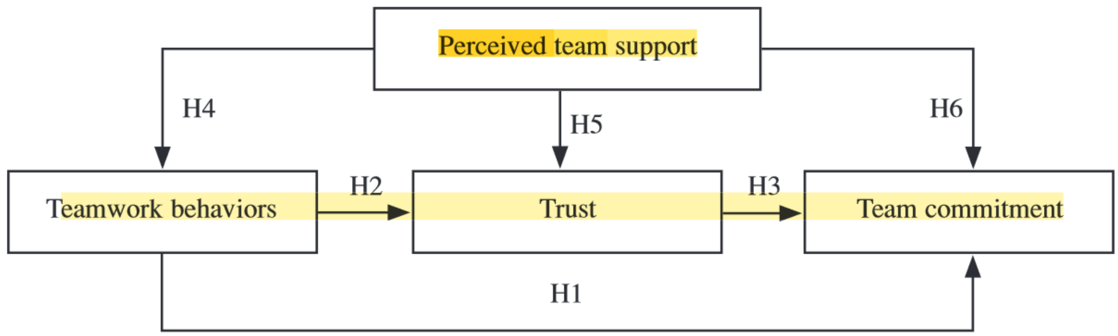

Figure 1A: Perceived Team Support

This is an on-going process as a team works together. They begin to form a cognitive-base of trust, which focuses primarily on achieving one's goals. If trust is formed within the team, the team members feel a sense of value and comfort, leaving room for a long-lasting relationship to form. If the team can coordinate, cooperate and communicate, the individuals will become more social and familiar with one another, leading the team members to amplify and strengthen the dyad (Sheng, 2010). This is important in the event that something happens unexpectedly and the dyad must work together in adapting and coordinating efforts.

Human-Machine Teams

Comparatively, human-machine teams show similar qualities to human teams. There is a large emphasis placed on the over-arching goals of human robot teams. These are safety, productivity, humanization, and environmental capability. Similarly, these goals have been used as a foundation within many human dyad environments. In establishing a productive human robot team, it is important that researchers start with the user. The users should be of high priority, specifically there goals, ability to achieve their goals and task analyses. These are strong components to not only an effective team in human dyads but also human robot interaction (HRI). Researchers should be empathetic of their users, centering the design of the robot on the human. This places emphasis on a human's cognitive processes, needs, and capabilities. By understanding the human, researchers have knowledge support when implementing new human robot dyads (Johannsen). Therefore, giving the robot the ability to appropriately respond in the event of something unexpectedly happening. Human dyads responses can be used as a model within human robot teams.

The communication and coordination methods studied within human's teams can be used as a baseline in human robot teams, in hopes to progress robots into being able to understand human intentions and needs. If a robot is empathetic of its user, they will be able to have trusted shared authority, potentially increasing stability and efficiency within the dyad (Johannsen). The stability in human robot interaction largely relies on the couple dynamic between human and robot, they must not only be stable as individuals but also as dyad. Stability and transparency allow for the robots motions to be understood by the user and create an environment where the robot can anticipate human intent. This ultimately will increase how the dyad responds to surprising events within the setting (Miller, 2017). If the two can be efficiently and effectively coupled it will lead to an overall seamless and safe interaction (Ajoudani, 2017).

Dyad Trust

Dyad trust looks at how an individual trusts a team member. In the context of this study, the term team member can refer to a robot partner or human partner. If an individual shows high levels of dyad trust, they are more likely to accept and rely on the person or system. As relationships develop trust is likely to change. These relationships can develop from continuous interaction or reliance on one another while completing a joint task (Jian, 1998).

In 1998 Jian developed a scale that took partnership within humans and compared it to human robot dyads. Jian, like similar researchers, found that humans associated these common terms with human trust and human robot trust, they are: trustworthy, loyal, and reliable. Trust should be comparatively looked at in human dyads and human robot dyads because trust is a construct only felt by living things (Evans, 2008). By understanding how human dyads create and form trust, researchers will be able to design and build a robot around the user. As the use of robotics increases, researchers must understand what humans feel. This will then help in creating an appropriate level of calibrated trust. If a human feels the robot is capable and empathetic of their needs, their levels of trust will match the robots abilities (Lee & See, 2004). This will ensure that robots can be designed to be high performing, responsive and explainable in all expected and unexpected settings, ultimately increasing trust (Miller, 2017). The researchers discussed below found other common trust terms that humans associated with human robot dyads.

Rempel et al. (1985) broke the basis of trust into three components: predictability, dependability, and faith. Predictability is the initial state humans face when working with a robot. Can they predict the anticipated actions of the robot? The component predictability can become clouded if the robot is required to respond to an unexpected event. The actions following the unexpected event may lead to a response from the robot that was unanticipated. This will largely affect the next component, dependability. Dependability is determining if the robot carries integrity, that is, is the robot’s behavior consistent and reliable. Researcher Tim Miller (2017) discussed designing a robot that is able to explain its action, ultimately making it more adaptable and explainable. If a robot is able to communicate its next steps in the event of a surprising occurrence the robot may not lose dependability. Conclusively, increasing faith within the human robot dyad. Faith is when the human has decided they are going to rely on the robot and its ability to carry out a joint-task (Rempel et al., 1985).

Lee and Moray (1992) also developed a similar framework with performance, process, and purpose. Performance answers the question of what the automation does. This is important for a human to initially answer to help in avoiding any levels of misuse or disuse. A human should have full understanding of what the automation is capable of. Process is how the automation operates. Humans may often times look past the inner working of the automation but it is important they have an understanding of the basis of its operation. This will benefit the user in the event that the human robot dyad is faced with a situation that is unexpected. If they understand the basis of its operation they may be more trusting that the robot can handle unexpected situations (Miller, 2017). Purpose answers the question of why the automation was developed. Robots were designed to aid and extend human performance, this is important to relay to low trusting individuals (Lee & Moray, 1992; Lee & See, 2014). With the understanding of these frameworks, researchers will be able to design a robot that can respond and explain appropriately within a human robot dyad.

Trust within teams largely relates to the team-members perception of its partners reliability and capability. If a team members perceptions accurately match their partner's abilities then trust is considered to be 'well-calibrated'. This is particularly important within human robot dyads (Joe et al., 2014). The goal of human robot dyads is to create a relationship that has well-calibrated trust, while also encompassing the components of a strong team. Stevens and Campion (1994) studied teams by exclusively focusing on knowledge, skill and ability. He drew several conclusions leading to a successful human team. These conclusions focused on conflict resolution, collaborative problem solving, and communication. This largely relates to an unexpected event interrupting a team while performing a joint-task. Team members must be able to recognize conflicts disturbing the team's interaction and collaborate on creating a solution. This requires strong communication channels that allow open and supportive conversation. Ultimately leading to stronger dyad trust between the two. If this framework is understood on a human dyad level and applied to human robot dyads then the goals and task coordination between the dyad may become stronger (Steven & Campion, 1994). Ultimately, creating a relationship that is predictable and dependable, while increasing faith (Rempel et al., 1985).

Stevens and Campion (1994) also discuss how interpersonal relations are important when looking at teammates. Interpersonal relations help researchers understand how humans maintain relationships, trust surrounding individuals, and react to other social constructs. This largely relates how they interact within a team-setting. High levels of interpersonal competence lead to team-effectiveness. Team effectiveness leads to better communication, conflict management, and overall positively facilitates the team. In the event that a team is interrupted by an unexpected occurrence they must be able to work as a unit in order to coordinate cognitive and physical efforts (Joe et al., 2014). If a robot is able to demonstrate these same abilities shown in human dyads, then humans will be able to calibrate their levels of trust to a robots capabilities, leading to a strong coupled dynamic.

With the potential of an unexpected event occurring in human and human robot dyads, it is important to understand trust at multiple dimensions (interpersonal and dyad). This will help researchers in understanding how unexpected events affect the dyads interactions. Researchers have found that the individual differences within a human's life largely effect how they trust new and existing relationships (Evans, 2008) (Steven & Campion, 2014). The question is, is there an effect with humans interpersonal trust and their dyad trust in human and human robot dyads. Typically, humans enlist trust differently in robot agents than they do human agents. Although, researchers have found that there are several attributes connecting teamwork and trust qualities between both dyads, they have not used the multi-dimensional concept within a comparison study (Jian, 1998). With the already established research, researchers can understand how humans develop and form appropriate levels of trust in human dyads. The results can be used as a comparative model for human robot dyads in expected and unexpected situations. This will help in identifying and building these same appropriate levels of trust that are found within human dyads in expected and unexpected situations.

RATIONALE

.Robots are being integrated into many dynamic environments that require them to act as a productive and responsive team-member. Within these joint-task environments robots will be required to aid humans in completing high-stake tasks that could determine the success of these companies. Specifically, in the context of this paper, the settings that will be focused on are industrial and space exploration. These settings require human robot dyads to potentially respond to emergency situations, unexpected events, or high-risk tasks. Humans must have well-calibrated trust with the robot's capabilities, this ensures the two are working as an effective team. The goal of this study is to use the human dyad findings as a model for human robot dyads, in hopes to mimic the historical effectiveness of human dyads within these settings.

The hypotheses for this study is four part and inspired by Nancy L. Stein's Goal Theory of Emotion (2001). If surprise levels are high and act a disruption to the human team, then dyad trust scores will be low. If surprise levels are low but still cause a disruption, then will dyad trust scores will be low. A disruption could look like a sudden response such as a loud scream or inability to effectively complete the task because of the unexpected event. This in turn would block the overall goal of completing the joint-task, causing the human to be less trusting of their partner. Ideally, low levels of trust would be reflected in Jian's dyad trust scale (Jian, 1998).

Hypothesis 3 is, trust scores will be higher if surprise levels go up with no disruptive behavior, causing the dyad to heavily rely on one another. If surprise levels go down, with no disruption, then it is expected trust scores will also be higher. If the team members respond in a way that increases team performance and effectiveness such as, non-verbally communicating, then it is projected that trust scores will reflect higher on the Jian dyad trust scale (Jian, 1998).. (Jian, 1998).

This study's main focus will not only be to understand how dispositional trust affects team coordination and performance (Rotter, 1967). But also how human team trust is effected after interrupted by an unexpected event while completing a joint-task (Jian, 1998). Human dyads will be used as a baseline model in hopes to transfer over the knowledge to human robot dyads. This study will be designed as a comparative model, focusing on human dyads and then using the results for future application of human robot dyads. The anticipated gain from this study is to understand how baseline levels of trust affect team interaction and how team interaction and individual trust is affected by unexpected events in human dyads.

A simulated, controlled lab will be designed in order to encompass human dyad joint-task interaction. The dyad will be asked to fill out a preliminary trust survey prior to any interaction. The goal of this survey is to identify the individual's baseline levels of trust. The dyad will then complete one of two conditions. Condition one will be a mundane joint task interaction. Condition two will have a series of random, unexpected interruptions while completing the joint task. Condition one or two will be randomly selected prior to the participants' arrival. Upon completion of the joint-task interaction, the individuals will be asked to take a post-survey. The goal of this survey is to understand how the joint-task interaction altered any levels of trust.

METHODS

Participants

All 34 participants were Arizona State University undergraduate and graduate level students. Students had to fit between the age range of 18 and 55. In order to protect the health and physical well-being of participants, they could not be pregnant or susceptible to heart disease. The joint-task required that the participants were able to lift 10 pounds comfortably with their dominant arm. The dyad was instructed to bend at the knees in order to prevent back injury. Any participants that were not in appropriate physical condition were instructed not to complete the study. It was heavily suggested that participants have not had any prior interaction to the study, as this may hinder the results. In the event that the participants had met before, a note was taken within their survey results.

These participants were chosen in order to gain the most accurate and appropriate results for the study. Participants were recruited through a software named SONA, which is a subject pooled geared towards Arizona State University students. Participants were also recruited in the student union where they had the ability to electronically sign up. Once participants signed up to participate in the study, they were sent a confirmation email that included a brief explanation of the study. Dyads had the option to receive class credit for participating, this was the only compensation they were offered.

Prior to the participants completing the study they took a preliminary trust survey. Survey results were used to establish an understanding of participants' general levels of trust. The Rotter (1967) Interpersonal Trust scale was used in order to obtain these results. Scores could range from 25 (lowest levels of trust) to 125 (highest levels of trust). Neutral ratings are shown with a score of 75. The highest score obtained from participants within this study was 102 and the lowest was 55. A distribution of the results is shown in Figure 2A. Most participants were considered average with their interpersonal trust ratings.

Results were analyzed using a scoring key given by Lawrence Wrightsman (1991). The score key followed the methodology of reverse scoring. The total of all the positive questions was taken down (1-5), and the total of all negative questions was reversed (5-1). After a value was given for each question, the values were added up to reach a grand total for the participants interpersonal trust score.

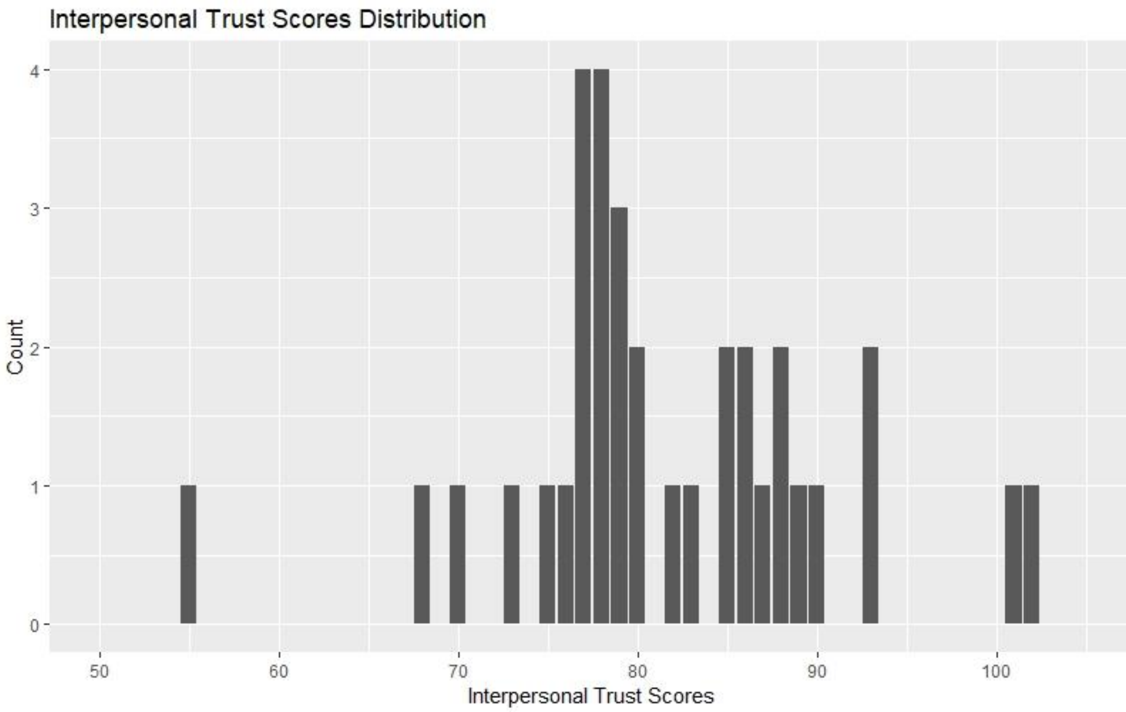

Figure 2A: Interpersonal Trust Distribution

Materials

There was a variety of materials used for this study. Each participant was given a consent form to read and sign, signed consent forms were stored within a file-cabinet of manila folders. A training procedure was given through google slides and shown on a laptop. All surveys (Rotter, 1967) (Jian, 1998) completed were administered by laptop. Participants completed consent forms, training procedures, and surveys on a 4-foot table. The table included two speakers, a blue outlined box, one subjective and one objective measure of surprise, and two laptops. Laptops were removed once preliminary tasks were completed and brought back for final post survey. The speakers were used for administered unexpected tones. Once tones were played, the researcher was instructed to fill out one subjective surprise questionnaire and a surprise facial expression checklist with seven choices. This checklist encompassed five common expressions linked to surprise and two interaction disruption expressions.

The joint-task required participants to work together in lifting a ten-pound box from the designated blue outline on the floor to the designated blue outline on the table. All outlines were completed with blue duct tape. The box was clear with two handles on either side, inside the box there was three bricks. The bricks were used in order to keep the weight appropriately administered. On top of the bricks was a measuring cup filled with 1 cup of water. Participants were instructed to stand on either side of the box, where there was either a number 1 or 2 placed on the floor.

In order to encompass full ranges of motion between dyads, six total motion sensors were used. They were placed on each individuals elbow and shoulder. The other two sensors were placed on opposite handles of the ten-pound box. Taped on the outside of the box was force sensors. Inside the controlled lab there was a total of six cameras. These cameras were used to connect to the force and motion sensors. Underneath the 4-foot table there was a small computer and speaker volume switch. These were connected to a hidden monitor.

The room was divided by a 9-foot black curtain. The curtain was used to separate the computer monitor from the participants. One researcher was behind the black curtain, coding data specific to each condition. On the other side of the curtain there were two participants and two researchers. Researchers were instructed to stand on opposite ends of participants in order to observe participants facial expression and administer the surprise questionnaire. The curtain was used in order to hide any potential priming effects. Participants were instructed to fill out the survey on either side of the table. While the participants completed the survey, researchers stood behind the black curtain. Once the participants completed all trials for their condition and filled out post-survey they were debriefed and taken to the front lobby.

Procedure

This study was broken down into two conditions. Condition one was considered a baseline condition and condition two was considered a surprise condition. The beginning of the study followed the same procedures regardless of the condition. Both participants were instructed to meet at the lab, where they were greeted by two researchers. The researchers instructed the participants to come in and make themselves comfortable. They were then each given a consent form to sign and turn in. Once participants completed consent, they introduced themselves to one another before any further action. After brief introductions the participants were asked to stand on either side of the table, in location one or two. They were each given a laptop where they would complete a preliminary survey (Rotter, 1967).

After the survey was completed the participants were guided through a brief training procedure. The training procedure honed in on the goals of the study, the restraints, and any common questions. Within the training procedure there was a quick demonstration that showed how two people work together to complete the task. The participants were then given an opportunity to ask any questions. After, the researchers took a quick break to place the motion sensors onto each participant’s dominant arm. They each had one placed on their elbow and shoulder. They were asked to briefly move around to figure out comfort levels. Once the training procedure was finished the participants completed a practice trial. The practice trial gave them the ability to get comfortable working together.

For each condition all five trials (including practice trial) followed the same joint-task. The participants were asked to work together in lifting the 10-pound box from the designated blue outline on the floor to the designated blue outline on the table. Participants were asked to wait for the researcher’s instruction to move the box up onto the table and then back down. The participants were asked to place their hands lightly on the handle of the box where the third motion sensor was located. Once the box reached its desired spot, the dyad was told to remove their hands from the handles, until instructed otherwise. Participants were coached not to communicate verbally or with gestures.

In condition one the participants completed all five trials with no interruptions. This was considered the baseline condition. They completed each trial, the same way, every time. In condition two (surprise condition) the participants were interrupted by a loud tone in trial 3 and 5. The tone was selected based on previous research on tones that grasp human’s attention. The tone was coded to go off .8 seconds after the dyad lifted the box. Within the training procedure, participants were told that if they heard a tone while completing the task to stop all movements until the tone came to a complete stop. Once the tone stopped, participants could finish completing the task. While the tone went off each researcher on either side of the participants filled out a facial expression surprise checklist. The checklist encompassed 7 different common expressions that occur in humans when surprised or disrupted (Landman et al., 2017). Two of the common expression, measured interaction disruption. After the tone came to a complete stop and the participants placed the box onto the table, each researchers asked the participants on a scale of 1 to 7 how surprised they were. Participants pointed to desired score and then completed the rest of the trials. This same procedure occurred in trials 3 and 5 of condition two.

After trial 5 of each condition the researchers removed motion sensors and answered any initial questions the participants had. Each researcher then brought their laptops onto the table so the participants could fill out a final post survey (Jian, 1998). The surveys Rotter (1967) and Jian (1998) each had a portion in which participants had to fill out their first and last name. This was strictly used for a comparison analyses, not for any record of the participants information. After the participants completed the survey, they were debriefed and sent on their way. Participants had the option to be emailed any results from the study.

Design

The variables that were analyzed within this study were the preliminary trust survey (Rotter, 1967), surprise measurements and the Jian dyad trust survey (Jian, 1998). The preliminary trust survey measured participants' dispositional trust levels (Rotter, 1967). The Jian dyad trust survey measured how trust was changed after completing a joint task together. The preliminary trust survey results are shown above. Results showed that most participants showed average levels of interpersonal trust prior to any interaction with their partner. After participants completed the preliminary trust survey they were broken into two conditions, surprise and no surprise. These two groups were considered the independent variables of the study. The Jian scale was used to test the effect on the two divided groups (surprise and no surprise). It was hypothesized that if the participant's goals were disrupted during the task or the task itself was disrupted that levels of trust would decrease. If participant's goals and/or task were not disrupted then levels of trust would reflect higher on the Jian dyad trust survey.

Data Analyses

This research project was considered an exploratory research analysis. Research was done in order to understand how the effects of unexpected events affected the Jian trust survey responses (1998). After completing the study, participants who participated in the surprise condition were coded in two groups. One group was based on their surprise metrics for Trial 3. The second group was based on their surprise metrics for Trial 5. This method was used to appropriately place participants based on their reaction to the surprise tone. All participants in the surprise condition were asked on a Likert scale of 7 how surprised they were, researchers simultaneously filled out a 7 choice facial expression checklist, based on these results participants were divided up.

All participants who recorded a 4 or higher in either surprise trial were considered surprised. The score of 4 or higher was chosen because this is the central point within the 7-point Likert scale. Participants who showed at least one facial expression and/or expression were also considered surprised. Within this facial expression checklist there were also two expressions that would measure interaction disruption. These questions focused on any sudden movements or noises from the participant that may cause a disruption during the interaction. Research found that no participants responded disruptively while completing the task. The other expression focused on the participants face. Facial expression has been shown to suggest the emotion of surprise, several people sub-consciously make expressions showing unconscious emotions (Lassalle, 2013;Nummenmma, 2008). This put a total of 15 participants in the measured surprise group Trial 3 and 1 participants in the measured no surprise group Trial 3. In the Trial 5 measured surprise group there was a total of 10 participants and in the measured no surprise Trial 5 group a total of 6 participants. After participants were broken up into groups, their individual Jian (1998) survey results were analyzed.

Participants were divided individually into measured conditions because of the simplicity of the task. The task given required little effort and cognitive ability. This caused any effects of the task or unexpected event during the task, to individually affect participants differently, making their individuals responses more meaningful then their results as a dyad. Participants showed stronger effects as an individual in surprise and Jian survey (1998) results. The Jian scale had the ability to potentially show interesting effects, changing how the results would be analyzed.

Based on the results given by the Jian scale, participants seemed to avoid answering questions 1 through 5. These questions were more focused on distrust, associating their partner with feelings that result in lack of trust. Several participants left this portion of the survey blank. This may show that participants are more comfortable associating positive words of trust with their partner. Jian found similar findings when doing word associations. Jian found that people perceived rating their partner distrusting seemed to have a negative connotation on participants, causing them to focus more on positive feelings of trust. With these results, Jian discovered that trust and distrust are considered opposite feelings but lie on the same dimension of trust (Jian, 1998).

An additional demographic analysis was ran in order to understand why there was a random drop off for questions 1-5. Researchers looked to see if there were any trends based on demographics (age, academic level or gender). Researchers found that there was no strong correlation between demographics and unanswered questions. The trend was found to be random and infrequent.

Therefore, the survey results for this study will only focus on questions 6 through 11. These questions emphasize the positive feelings of trust. The focus of this paper was to figure out how individual's levels of trust are effected when interacting in a dyad. The focus was to primarily figure out if their levels of trust become higher or lower depending on an unexpected event. Thus, removing any questions associated with distrust will not result in a large lack of information. The scale of positive trust questions will allow the researchers to determine if the individuals associated positive feelings of trust within the dyad, any low scores shown on questions 6 through 11 will convey any feelings of lack of trust.

Participant's individual Jian scores were analyzed similarly to Rotter's interpersonal trust survey. Although, the scoring would not be considered reverse scoring because of the absence of the negative questions within the Jian scale. Therefore, all participants positive scores (1-7) were recorded in order to achieve a grand total for their dyad trust levels. The highest score an individual could score on the Jian scale was 42 and the lowest score was 6.

These dyad trust levels were organized into a total of three groups. Participants who were classified as being surprised based on the surprise metrics were placed based on the trial they showed surprise. All participants who were considered not surprised were placed into another category. These groups were considered the measured surprise group trial 3 (n = 15) and the measured no surprise group trial 3 (n = 1). Measured surprise group trial 5 (n = 10) and measured no surprise trial 5 (n = 6). Participants were also individually broken up into their condition group. All participants who participated in the surprise condition, whether surprised or not were placed into this group (n = 16). All participants who participated in the baseline condition were placed into this group (n = 18). These two categories were considered the surprise condition and the baseline condition. An analyses were run on all 3 groups to compare how trust levels were affected based on placement within the 3 groups.

RESULTS/DISCUSSION

Jian's scores were achieved by taking a grand total of response ratings. This was done rather than taking the average of the responses. Taking the average can lead to the result of hiding or distorting information, leading to a misinterpretation of the data (Gob et. al, 2007). Therefore, for all surveys the total scores were taken in order to obtain an accurate understanding of the participants' responses. After, an analyses (t-test) was ran in order to understand how the measured surprise group (trial 3 and 5) and measure no surprise group (trial 3 and 5) compared to one another. An additional analyses (t-test) was run in order to understand how the surprise condition and baseline condition compared to one another. The group's total Jian scores were divided into a table and used to find the t-score. This was considered a two-tail test analyses because the two group's means were being used to find the difference between the two.

It was hypothesized that participants who felt that the unexpected event acted as a disruption to the task or the goals of the task then low scores of trust would be reflected on the Jian scale. With the study results, no participants showed or unconsciously responded to the disruption metrics. Therefore the two hypotheses discussed earlier encompassing disruption will not be referenced. It was hypothesized that participants whose goals were not affected or disrupted during the unexpected events, regardless of levels of surprise, would show moderate to high levels of trust on the Jian dyad trust survey (1998).

First, the surprise condition and baseline condition were looked at to understand if there was a difference within the initial dataset. The trust levels of the surprise condition group (M = 37.06, SD = 5.99, n = 16) were hypothesized to be higher (if not disrupted) than the trust levels of the baseline condition (M = 33.39, SD = 8.85, n = 18). The difference between the two groups was not statistically significant, t (32) = 1.4, p = .17 (2-tail). A small t-score shows that the groups were found to be statistically similar, therefore showing no major changes of trust levels between the groups. Below a graph is included that shows a bar graph with each groups means. The bar graph includes 95% confidence intervals. These confidence intervals overlap one another, showing that there is no significant difference in the two data sets.

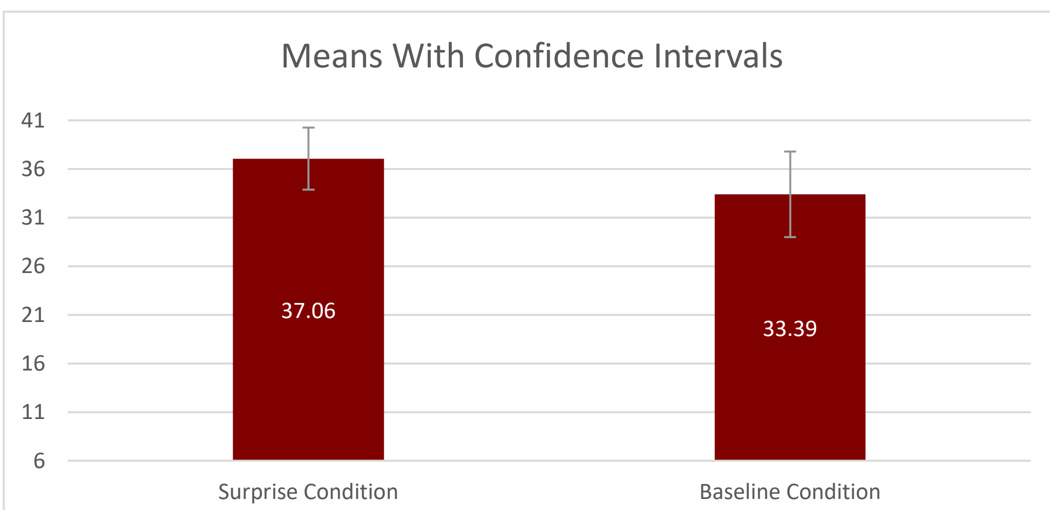

Figure 3A: Means with 95% Confidence Intervals – Surprise Condition and Baseline Condition

Second, the measured surprise and measured no surprise groups were looked at. The measured surprise group trial 3 (M = 36.73, SD = 6.05, n = 15) and measured no surprise group trial 3 (M = 42, n =1) were analyzed. These results were unable to be appropriately analyzed based on the small sample size in measured no surprise trial 3 group. These results did not show statistical significance for higher ratings of trust $t(14)$ = .87, p = .41 (2-tail). These results potentially did not show significance because of the small sample size. It is common that more participants responded surprised for the first surprise tone administered, the groups responses on surprise varied more for the trial 5 phase. The trial 5 phase was a more meaningful data set to analyze because participants took the Jian (1998) survey directly after this administered surprise.

The measured surprise group trial 5 (M = 37.5, SD = 4.74, n = 10) and measured no surprise group trial 5 (M = 36.33, SD = 8.14, n = 6) were analyzed. It was projected that these results would show the most meaning. Although, these results also did not show statistical significance t (14) = .37, p = .72 (2-tail) for higher levels of trust. This low t-score shows that the two groups did not show enough statistical significance with the Jian (1998) survey responses. Below is a bar graph that includes 95% confidence intervals. These intervals also show that there was a large overlap between results in the measured surprise and measured no surprise group. Responses varied tremendously within the measured no surprise group. This is shown with the wide confidence interval. Responses were much narrower within the measured surprise group.

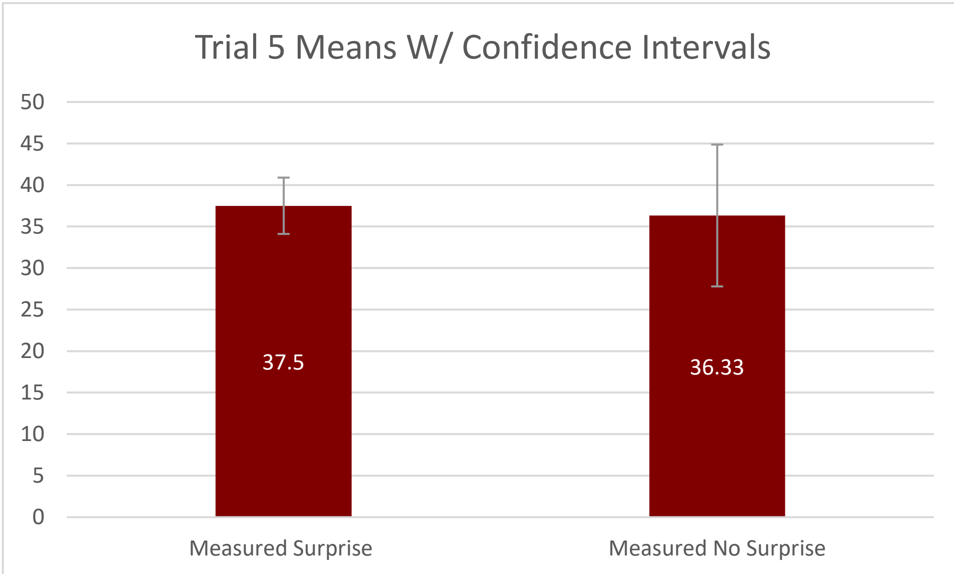

Figure 3B: Trial 5 Means with 95% Confidence Intervals

These statistics show that the participant's goals were not affected or disrupted while interrupted by the unexpected event, resulting in no negative effects on individual dyad trust levels. Participants actually showed higher levels of trust when completing the surprise condition. This could mean that when participants were interrupted by the unexpected event they became more reliant on one another, resulting in higher levels of trust. These high levels of trust are shown above with the surprise condition having a ($M = 37.06$). This could be in relation to the participant's average to high levels of interpersonal trust (Rotter, 1967).

Literature shows that participants who demonstrate higher levels of interpersonal trust are more likely to encompass team effectiveness and coordination. Participants likely, accepted vulnerability and uncomfortableness and used that energy to work in a more trusting dyad (Stevens & Campion, 1994).

Interestingly, individuals showed lower Jian trust averages in the baseline condition and the measured no surprise trial 5 group. This may be because participants were not required to work through an unexpected obstacle, causing them to not become more reliant on their partner. Although, even though trust levels were shown to be lower in the baseline condition and the measured no surprise group, trust levels were still overall considered high.

These results support Nancy L Stein's Goal Theory of Emotion (2001) because she states that people whose goals are blocked or disrupted while completing a task are more likely to become less trusting of an individual. Within this study we found that all participants were successful in completing the task. All participants were able to successfully lift the box onto the designated area. If participants struggled in completing the joint-task or were unable to successfully lift the box without spilling the cup of water then the goal of the task would be blocked or disrupted, potentially leading to lower trust levels. Nancy L. Stein states that people whose goals are not blocked and rather are supported become more reliant on one another. This same effect was seen within the study design, supporting the hypotheses posed (Stein, 2001).

Most participants trust became higher when interrupted by the surprising event. This result is still important to this particular study because understanding how human dyad interaction is different from human robot interaction is imperative. It is hypothesized that these results would be statistically significant in the event that the researchers were studying human robot interaction. Based on the results humans tend to show more trusting behavior when put in a new, vulnerable situation, they become more reliant on their partner and their partners ability. This same effect is hypothesized to be different in human robot interaction. Humans are less trusting of robots and any vulnerability or uncomfortableness caused by an unexpected event would result in the dyad to become less trusting (Lee & See, 2004). We found that humans teamed up during the unexpected effect, causing the interaction to be strong. Because recent research shows that these same teaming and trusting effects would not be found in human robot interaction, it is important to comparatively look at human dyad interaction (Turkle 2004; 2010) (Jian, 1998). The results gained from this study can be used to model human robot interaction to be very similar to human dyad interaction. The hope is to gain enough insights from human responses to be able to fully understand and empathize with human emotion. By understanding human emotion researchers will be able to develop a robot that is empathetic of its user, resulting in the robot being a better and more efficient team player (Ajoudani, 2017). Human robot interaction is something that is unavoidable in future applications and designing a robot that can be as efficient and empathetic as a human partner is necessary for the safety and well-being of the human species (Steven & Campion, 1994).

LIMITATIONS

With exploratory data analyses there are several limitations that must be considered. In order to design an appropriate, efficient human robot model the goal was to study human coordination while completing a joint-task. For surprise condition an unexpected event was controlled to go off twice while the human dyad completed the joint-task. A limitation that must be considered is the study design had no ability to control participant reaction. Both participants were volunteers, no confederates were used within this study. A confederate participant would give the researchers the ability to control the environment more, making the one participants reaction the only focus of the study. Significant results may have been found if the researchers were able to control for a confederate to cause a disruption during the unexpected event. It was decided to study raw human to human interaction so the results would be genuine and truly capture the interaction between the two. This allowed for the outcomes obtained to be candid but could of lead to unplanned circumstances within the results.

Although, because the task was considered simple it had the potential for participants to show no effect when working together in a dyad. The task required little effort and could have been completed in a single person setting rather than a team-setting. This lead to understanding the results of the individual within the teams to be more meaningful. This limits the researchers ability to understand how unexpected events and surprise truly effect team-coordination and communication methods because of lack of complexity and high-risk settings. If the task had been designed to more complex and intricate then the two participants may have sub-consciously worked as a team more.

Likert style surveys also limit the information obtained from the interaction. Likert scales leave room for participants to answer questions untruthfully, this could be from biases or lack of understanding of the content. Likert style surveys are likely not sensitive enough to truly capture human responses. Participants are limited to sharing how they feel about something. This was shown when participants failed to respond to the negative questions (1-5) of the Jian survey. This could have been because of feelings of uncomfortable-ness or understanding of the context of the question. This limits the information gained from the surveys, making it difficult to make strong predictions from the results.

The Jian scale metrics left room for assumptions to be made about feelings of trust, making it difficult to draw strong conclusions from the results. The Jian scale could have been more effective if participants were instructed to take it after both trial 3 and trial 5. The researchers may have found more a statistical effect with feelings of trust if participants trust was measured immediately after the surprise administered. Researchers did not design the study this way in order to avoid priming effects. The fear was that the participants would catch on to what was being studied and in turn not answer truthfully. The Jian (1998) survey could have also been given as a pre-test, along with the Rotter (1967) preliminary survey. Although, the purpose of the Jian survey was to encompass how participants feel about their partner after completing a joint task. Researchers decided against giving Jian (1998) as a pretest because participants would not be interacting with their partners prior to completing this survey. This could have led to results being superficial, making them insignificant to the research study.

Participants were broken into groups based on the results from the surprise metrics. Their Jian scores were organized accordingly. The surprise metrics used may have limited the study, making the organization method not very strong. Surprise was measured two ways for this study. The participants were asked on a scale of 1 to 7 how surprised they were. It was decided that because 4 was the central point within this scale, that it would be used as the threshold for surprise. One way to help this limitation was by putting another surprise metric in place. This was done by creating a 7 choice facial expression checklist. This checklist was established based off of the literature found on surprise (Landman et al., 2017). The literature showed that when people feel the emotion of surprise they likely make some kind of facial expression. Based on this literature, the facial expression check list proved surprise if at least one expression was shown during the surprise trials. Results showed that some participants who considered themselves a 3 or lower on the surprise scale showed something different with their expressions.

The facial expression data creates its own limitation because no facial expression software was used. The researchers within the study made all judgement calls for the facial expression data. This limits the reliability behind all the facial expression assumptions. Researchers hoped to gain stronger reliability by putting two surprise metrics in place, these metrics were strictly used to make the surprise data stronger.

CONCLUSION

The use of robotics is quickly being integrated into several dynamic environments. Robots are expected to aid and extend human performance, efficiency and overall productivity (Sparrow, 2005). In order to ensure that robots are being used to their full appropriate, potential, researchers must understand and empathize with the user.

The aim of this study was to answer the research question: Do unexpected events in a joint-task setting affect individual levels of trust when working in a team? Does a disruption created by a team-member, during an unexpected event, have an effect on trust levels? The results showed that human dyad trust is much stronger than what literature shows for human robot trust (Jian, 1998). The relationship between human dyads showed a positive effect on trust after interrupted by an unexpected event. Surprise seemed to heighten participants' levels of trust, compared to the no surprise condition. Participants did not react in a disruptive way, making it difficult to understand how this could affect individual levels of trust. From this study, the conclusion can be drawn that humans trust levels should be extensively understood. Prior to modeling human behavior in a human robot setting, humans trust levels should be better studied in more complex, high-risk environments. This is will ensure that the integration of robotics in joint-task environments is effective and seamless.

Humans are essential to the coordination and communication methods in human robot teams. By researchers understanding how a human feels emotion, responds to unexpected situations, and interacts with partners, they will be able to model the historical effectiveness of human teams in human robot teams (Joe et al., 2014). Research shows that humans naturally associate human qualities to robots, making it difficult for them to create an appropriate distinction between human and robot (Turkle 2004; 2010). If researchers can use established research between human teams and apply it to human robot teams they may have the ability to model an efficient human robot team (Jian, 1998) (Ajoudani, 2017). This would allow the sub-conscious associations between human and robot to not be so detrimental to the success of the relationship. If a robot can mimic human behavior and reliability then acceptance could potentially rise. Not only should human dyad team's trust and adaptability be understood but also other effective human teams. Such as human dog teams, by understanding how humans interact with a diverse group of living things, researchers may be able to understand fully how humans encompass emotion.

Understanding human emotion and how it relates to living things surrounding it is detrimental to the success of these relationships. Humans respond to unexpected events in various different ways and as researchers if we understand these responses and communication channels, we can better understand how to design an adaptable, responsive agent. If researchers understand how humans communicate in a diverse setting then all complexities of emotion will be better understood.

Trust is a large altering factor within these relationship and it has become essential that researchers understand how trust effects dynamic relationships. Trust has the ability to create a strong bond, increasing reliability and leading to well-calibrated levels of trust (Lee & See, 2004). Trust trumps vulnerability and uncertainty, ultimately leading to a better coupled dynamic between two individuals (Atkinson & Clark, 2013). Trust is often over-looked in the design of assistive robotics. But as the ability of technology increases and the integration of robotics become essential, it is important to study trust at multiple dimensions (Evans, 2008). By understanding trust at multiple dimensions, researchers will be able to develop a robot that has integrity and other innate trusting qualities.

This study design was used to encompass the effects of unexpected events and trust in human dyad interaction. The study design found that humans become more reliant and trusting when interrupted by an unexpected event. These results can help in designing a robot that incorporates more human like qualities in order to ensure their mechanical and social responses ensure safety, efficiency, and productivity. Studying human coordination and communication channels can help in aiding the modeling of human robot interaction by designing and coding robots to be more empathetic of its user. As human systems engineer it is important to remember that that the existence of robots is only as strong as the user interacting with it.

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APPENDIX A

PRETEST (ROTTER, 1967) SCREENSHOT

Interpersonal Trust Scale

Directions: Indicate the degree to which you agree or disagree with each statement by using the following scale:

1 = strongly agree
2 = mildly agree
3 = agree and disagree equally
4 = mildly disagree
5 = strongly disagree

1. Hypocrisy is on the increase in our society.

1 2 3 4 5

2. In dealing with strangers one is better off to be cautious until they have provided evidence that they are trustworthy.
3. This country has a dark future unless we can attract better people into politics.
4. Fear and social disgrace or punishment rather than conscience prevents most people from breaking the law.
5. Using the honor system of *not* having a teacher present during exams would probably result in increased cheating.
6. Parents usually can be relied on to keep their promises.
7. The United Nations will never be an effective force in keeping world peace.
8. The judiciary is a place where we can all get unbiased treatment.
9. Most people would be horrified if they knew how much news that the public hears and sees is distorted.
10. It is safe to believe that in spite of what people say most people are primarily interested in their own welfare.

APPENDIX B

POST-TEST (JIAN, 1998) SCREENSHOT

Question	Concept(s)
~~1.My partner is deceptive.*~~	~~Deception, lie, falsity, misleading.~~
~~2. My partner behaves in an underhanded manner.*~~	~~Sneaky, steal.~~
~~3. I am suspicious of my partner's intent or action.*~~	~~Mistrust, suspicion, distrust.~~
~~4. I am wary of my partner.*~~	~~Beware.~~
~~5. My partner's action will have a harmful or injurious outcome.*~~	~~Cuel, harm.~~
6. I am confident in my partner.	Assurance, confidence.
7. My partner provides security.	Security.
8. My partner has integrity.	Honor, integrity.
9. My partner is dependable.	Fidelity, loyalty.
10. My partner is reliable.	Honesty, promise, reliability, trustworthy, friendship, love.
11. I can trust my partner.	Entrust.

APPENDIX C

IRB APPROVAL

APPROVAL: MODIFICATION

Wenlong Zhang
Polytechnic Engineering Programs (EGR)
-
Wenlong.Zhang@asu.edu

Dear Wenlong Zhang:

On 1/16/2019 the ASU IRB reviewed the following protocol:

Type of Review:	Modification
Title:	Measures of Reliance in Physical Human-Machine Coordination
Investigator:	Wenlong Zhang
IRB ID:	STUDY00006691
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• reliance in pHMC_questionnaire, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • reliance in pHMC_cv_co-PI, Category: Vitaes/resumes of study team; • consent, Category: Consent Form; • reliance in pHMC_flyer, Category: Recruitment Materials; • reliance in pHMC_recruitment email, Category: Recruitment Materials; • reliance in pHMC_cv_PI, Category: Vitaes/resumes of study team; • Recruitment Email, Category: Recruitment Materials; • reliance in pHMC_protocol, Category: IRB Protocol;

The IRB approved the modification.